

# Shower/Track separation in ProtoDUNE-DP

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EM showers reconstruction is one of the main interests for DUNE

- **$\gamma$  conversion induced cascaded** background for  **$\nu_e$ CC event**  $\rightarrow$  **electron induced cascades.**
- **Photon conversion gap** between the  $\nu$  interaction vertex and the shower starting vertex is a powerful discriminant, but **difficult to detect** (Topology)
- **dE/dx at the beginning of the cascade is discriminating between signal and background events** (double m.i.p. from  $\gamma$  conversion)
- **Cascades from single electrons** and **from  $\pi$  in 6x6x6**
- **Some em activity from cosmic rays in 3x1x1**

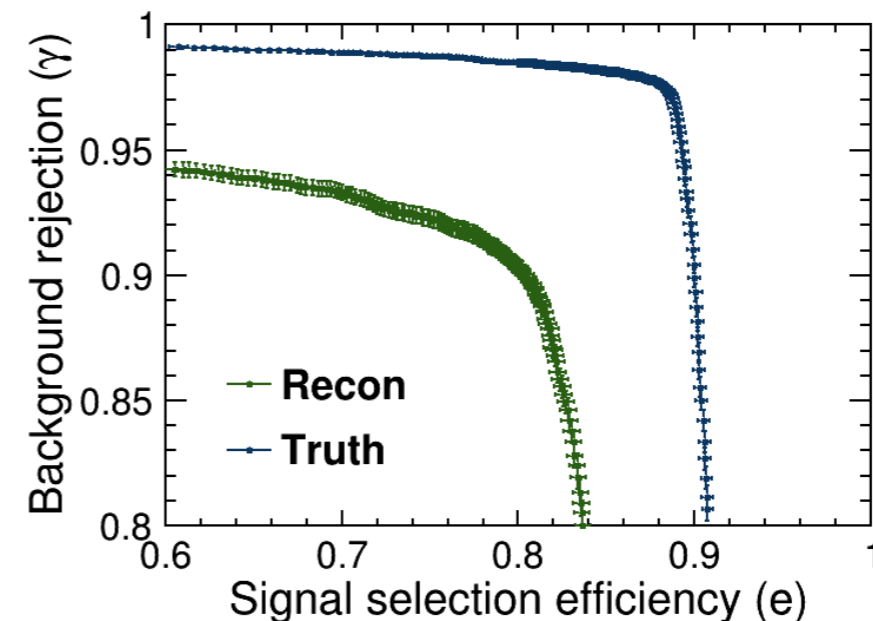
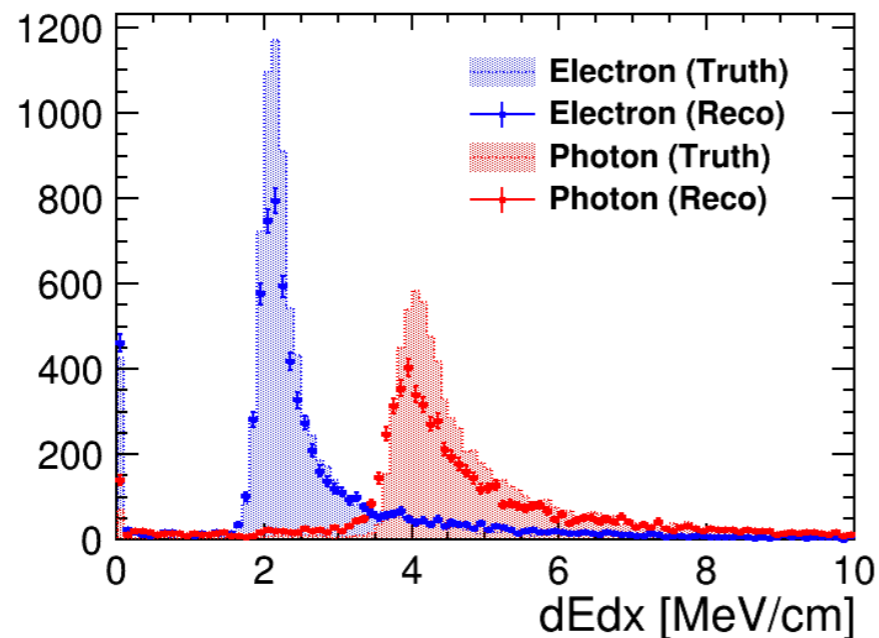
## In this presentation

- Recap on: e/ $\gamma$  using stopping power (for Single event only )
- Application of a Convolutional Neural Network in ProtoDUNE-DP
- First observation on track/em hit tagging

# e/ $\gamma$ separation in DP

Studies performed this winter (see [link below](#)) in the dune FD-DP working space geometry with **single events of photons and electrons** between 0.2-5 GeV

- Assess **Shower reco** for DP
- First look into **Shower calibration and reconstruction efficiency**
- **First look into e/ $\gamma$  separation capabilities in dp**
  - Classification strongly relies on truth information
  - Simulation and geometry not realistic (No noise, rotated geometry, ...)

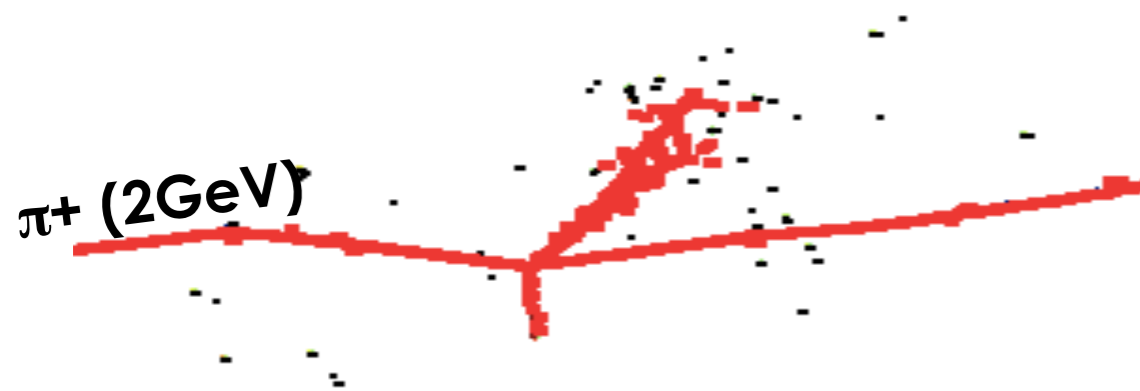


**Links:** <https://indico.fnal.gov/getFile.py/access?contribId=22&sessionId=4&resId=0&materialId=slides&confId=13938>

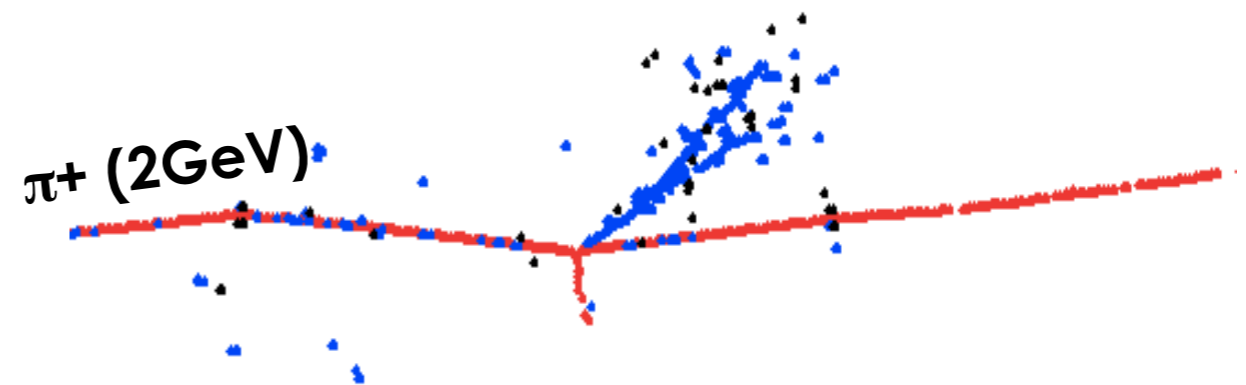
# Convolutional Neural Network (CNN)

Standard reconstruction is not very effective: Track and Showers usually mismatched in confused events: analysis complicate.

With standard reco:  
“emshower”



Hit labelled by CNN



The CNN approach is different:

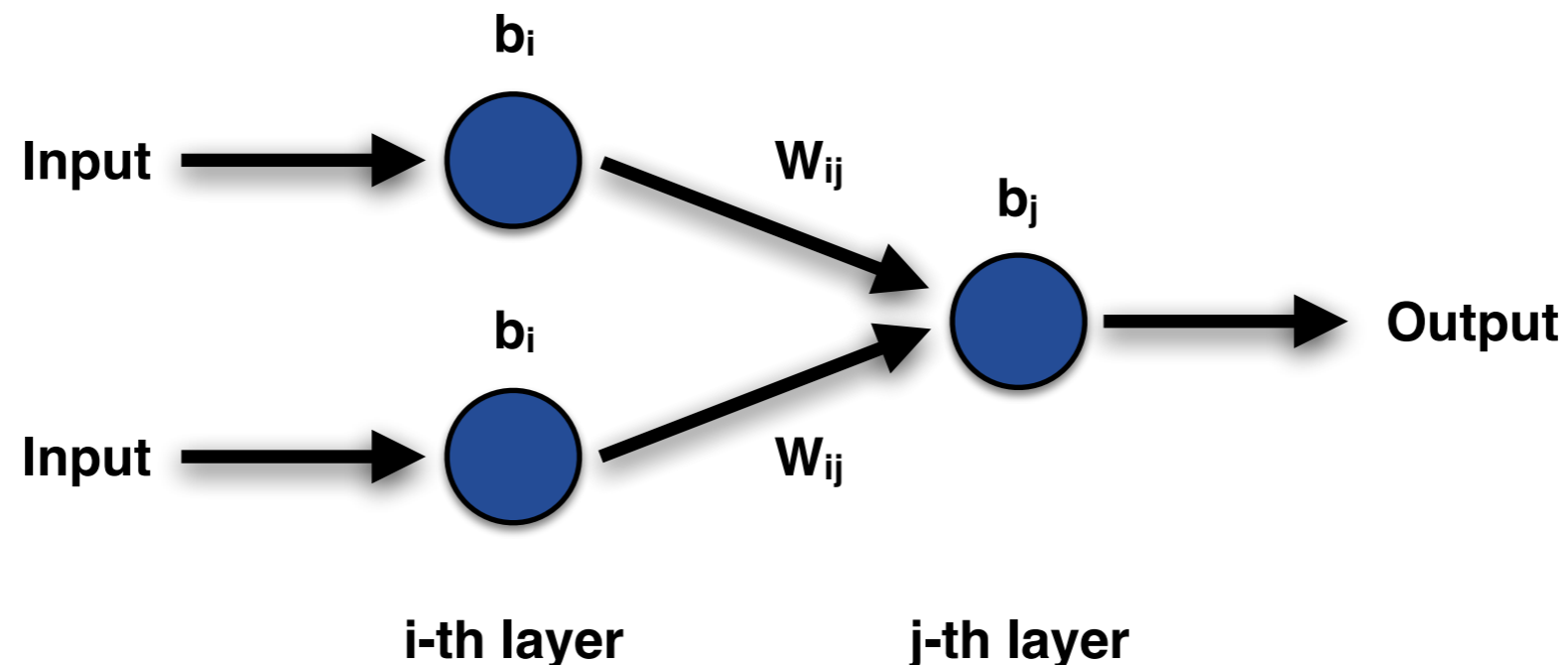
- Each hit is classified to be **em-like**, **track-like** or empty.
- Sub-classes are possible (em-like it can be also Michel electron).
- Type related algorithms can be run only on target type hits

**I am trying to apply CNN on Dual-Phase**

# CNN in a nutshell

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- Definition of the problem determines the type of training
  - Preparation of a specifically selected training sample of input
  - Network architecture
- Network is trained to classify the input by minimizing a specific function describing the discrepancy between the obtained and expected output, adjusting the weight ( $w$ ) of the neuron connections and the neurons activation thresholds ( $b$ )
- Periodic controls during training epochs using a testing sample to assure the predictability of the network output

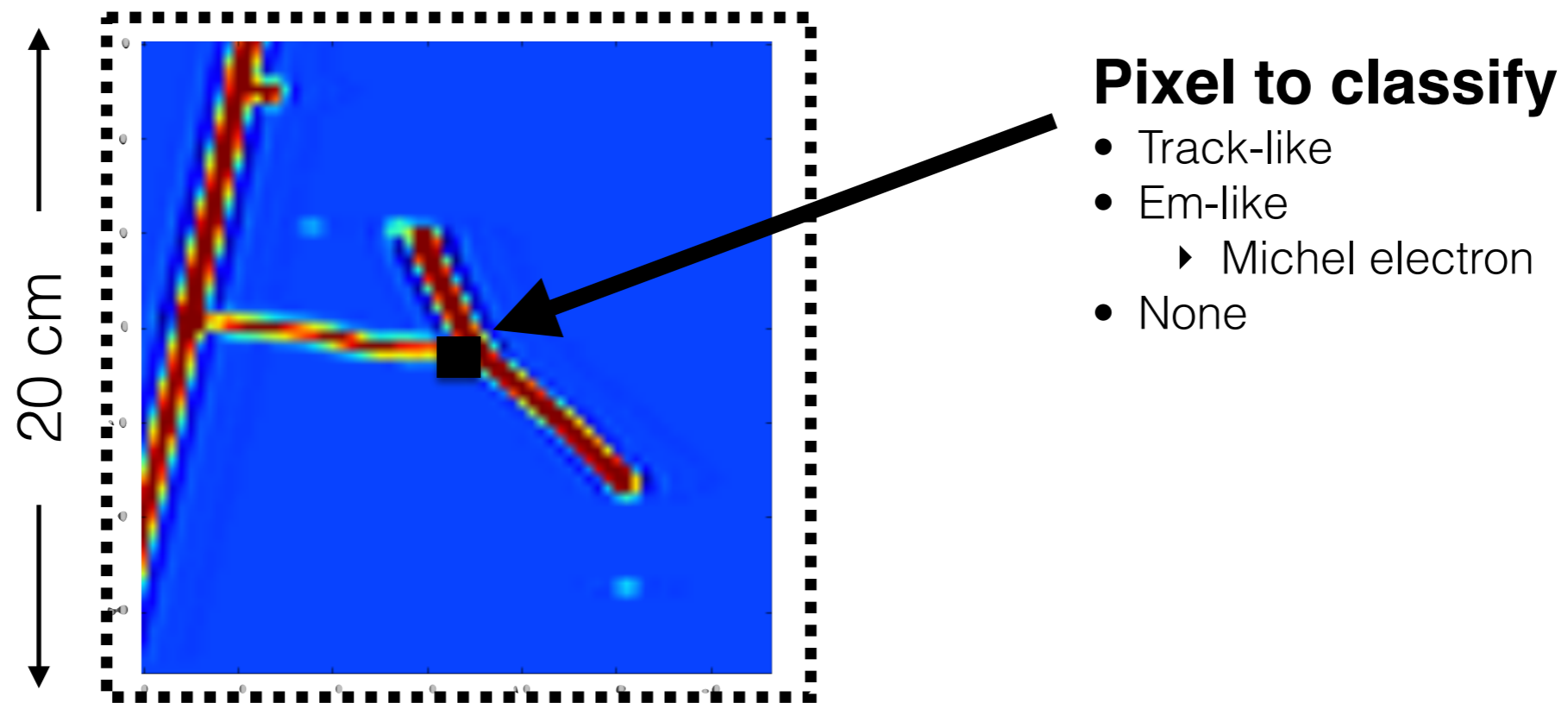


# Data Preparation

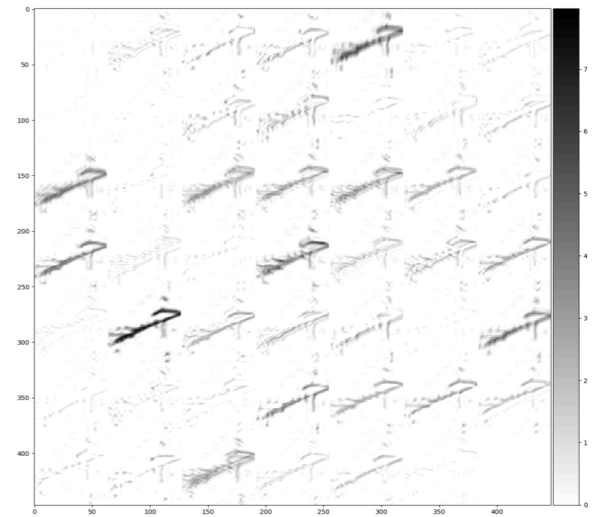
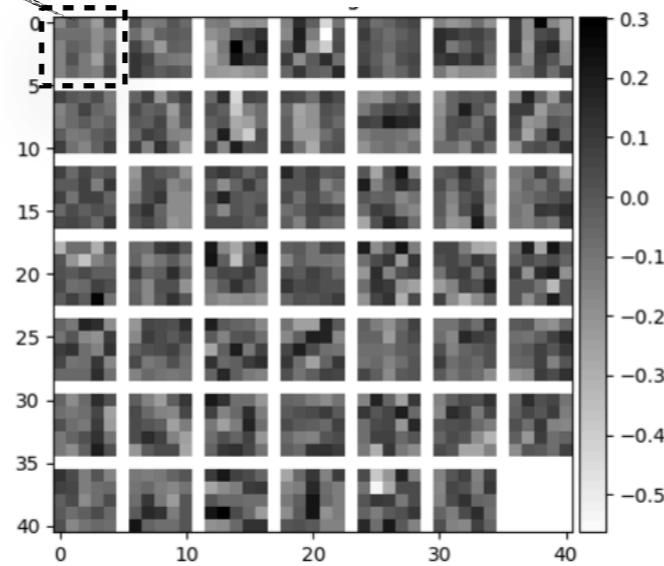
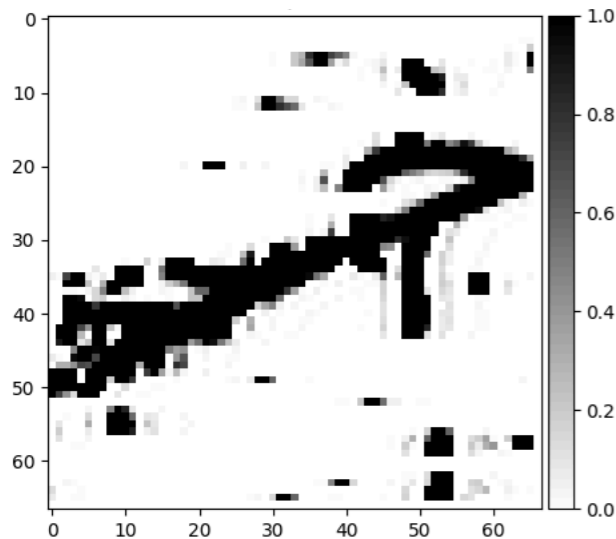
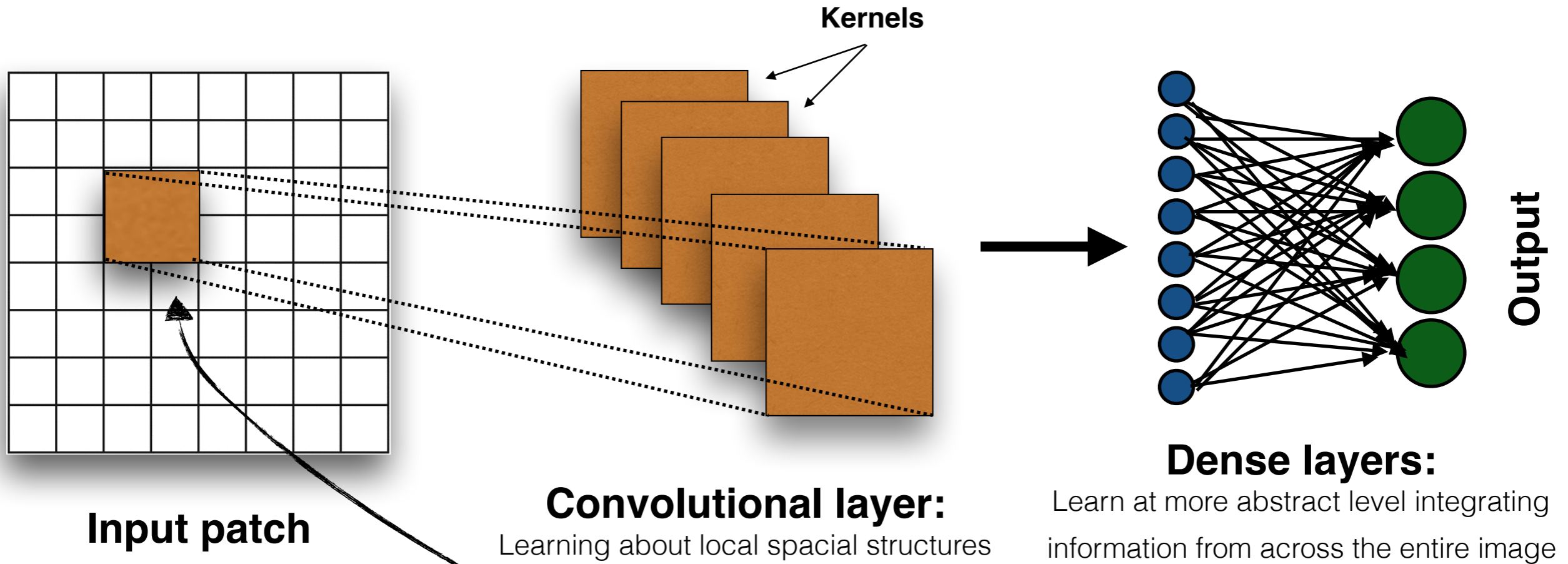
Following the trail from Robert, Dorota and Piotr from SP: Single pixel classification provided based on the “context”.

The “**context**” is a 20x20 cm<sup>2</sup> patch. Pixels sizes depends on the wire spacing:

- 5 mm for SP
- **3 mm for DP** → Potentially allowing larger resolution for finer pattern detection



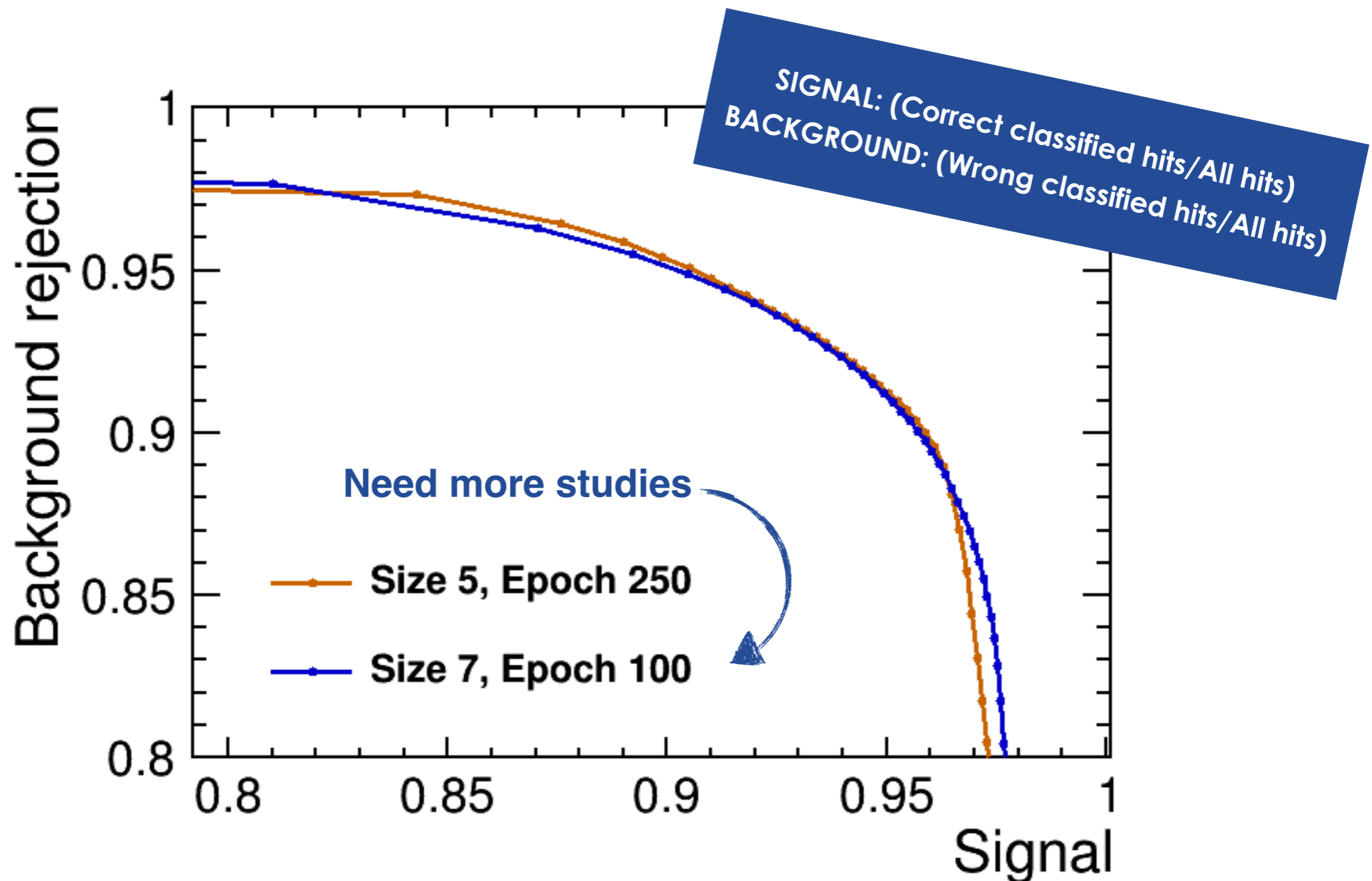
# Example of a CNN



# Performances of the models

Two models tested (thanks Robert!!):

- ▶ Kernel size 5x5 : same as SP
- ▶ Kernel size 7x7: better, in principle, for the finer resolution of DP

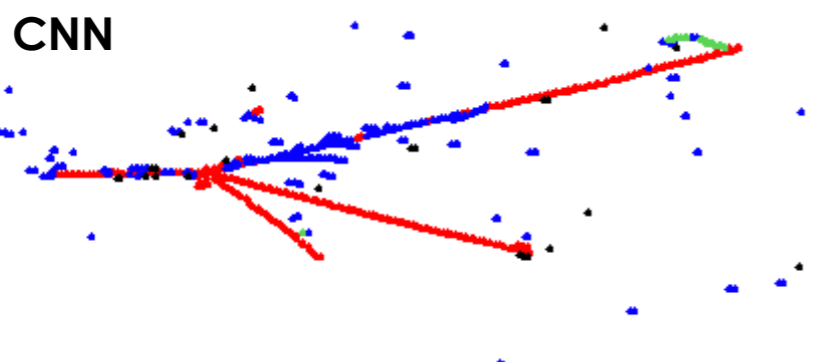
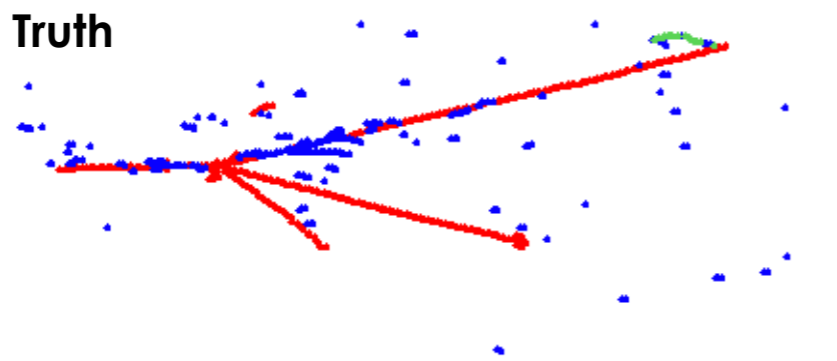
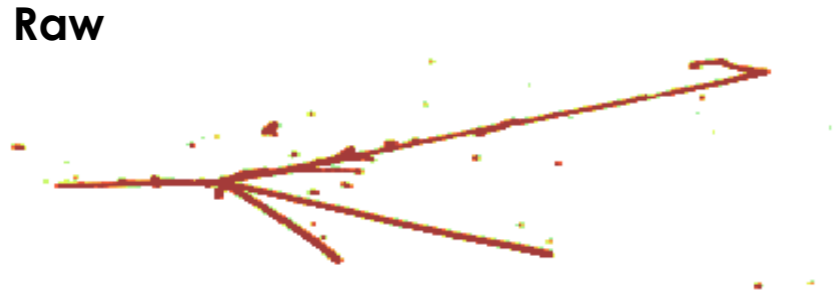




# Event display

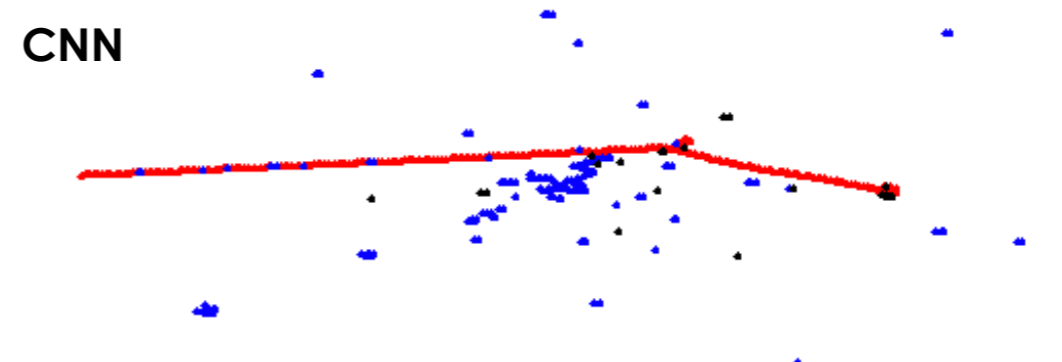
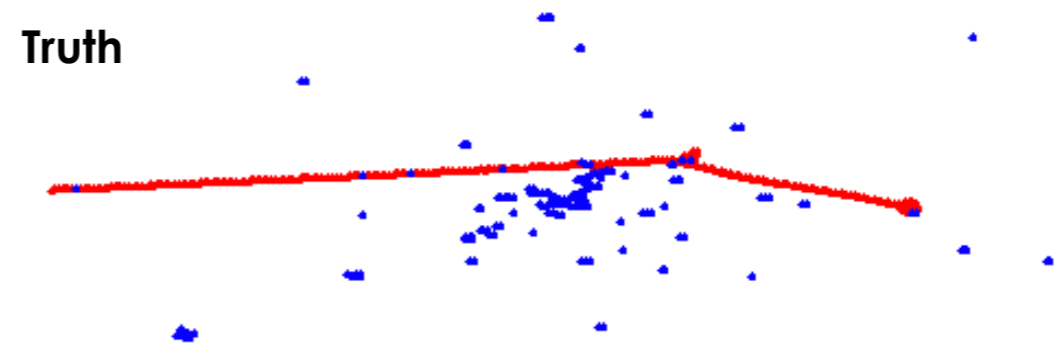
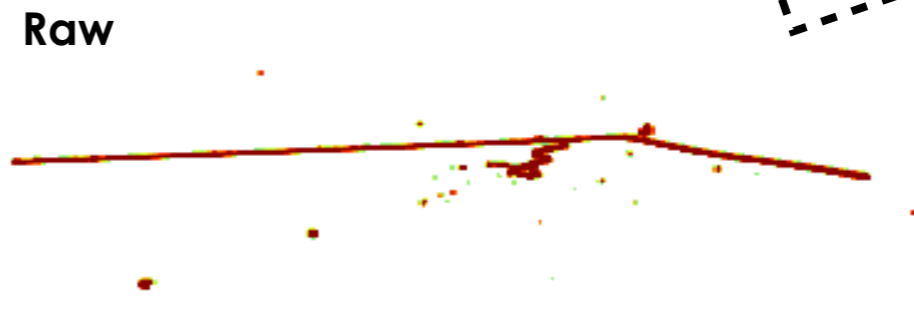
View 1

Pion 2GeV



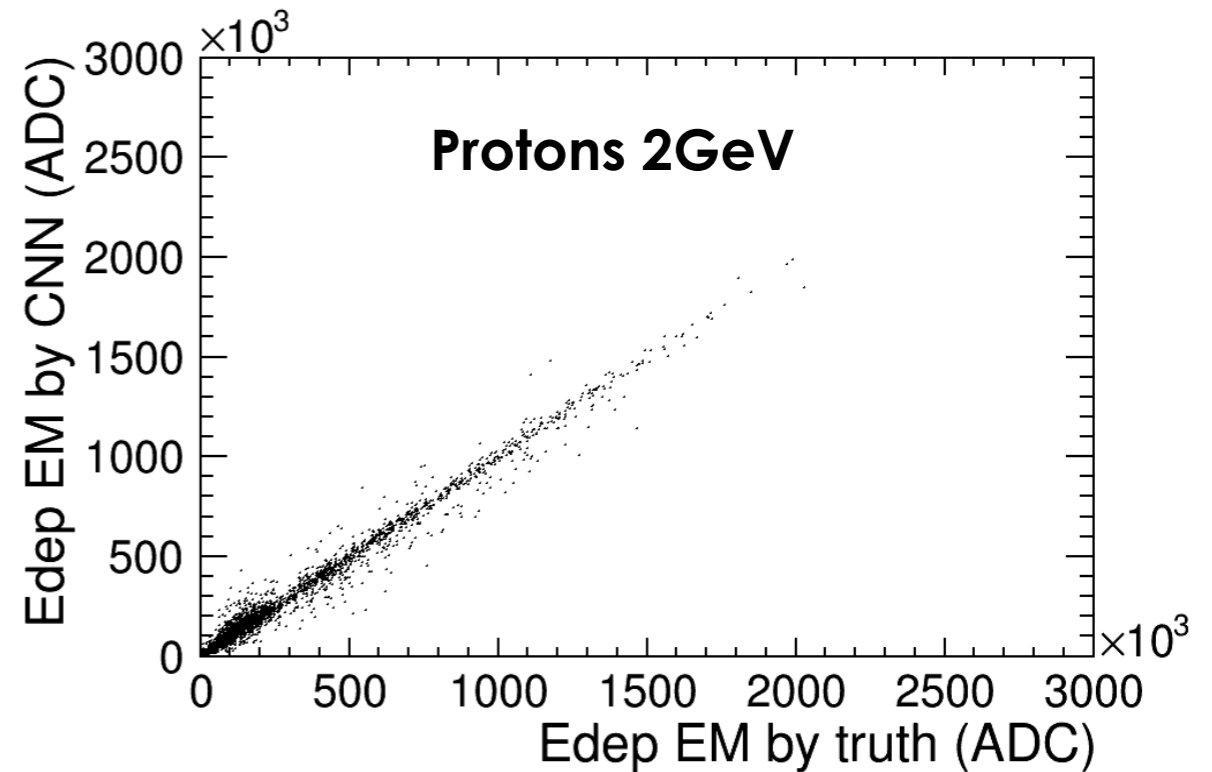
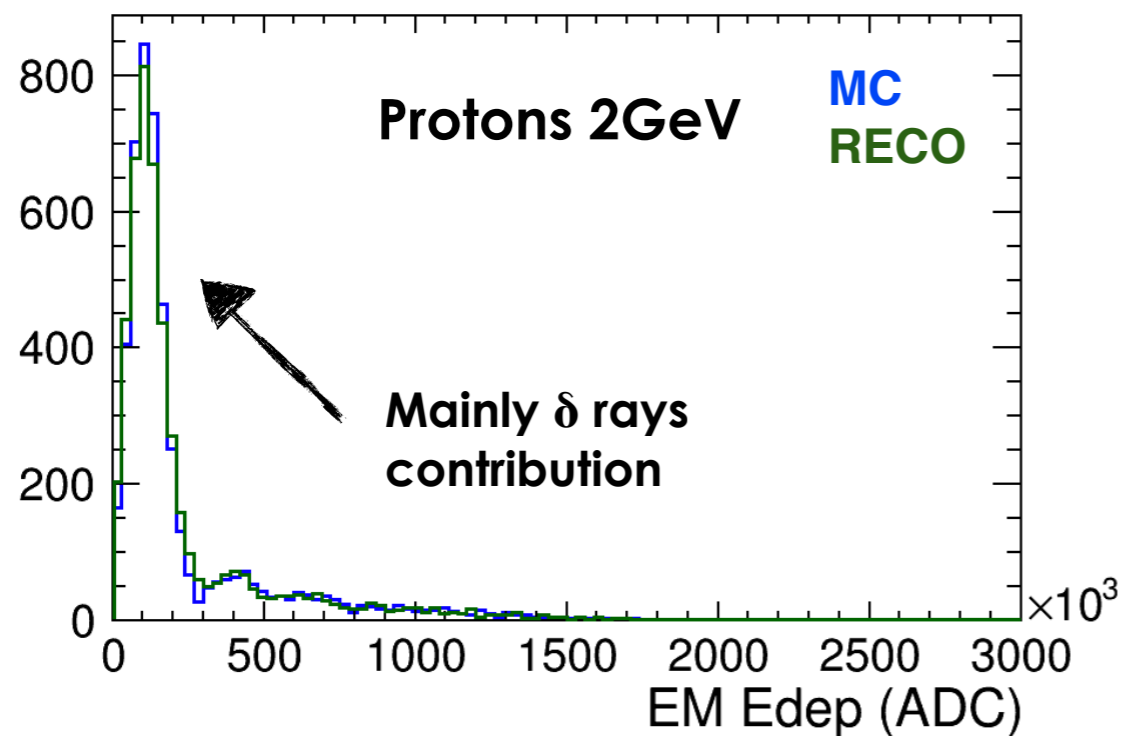
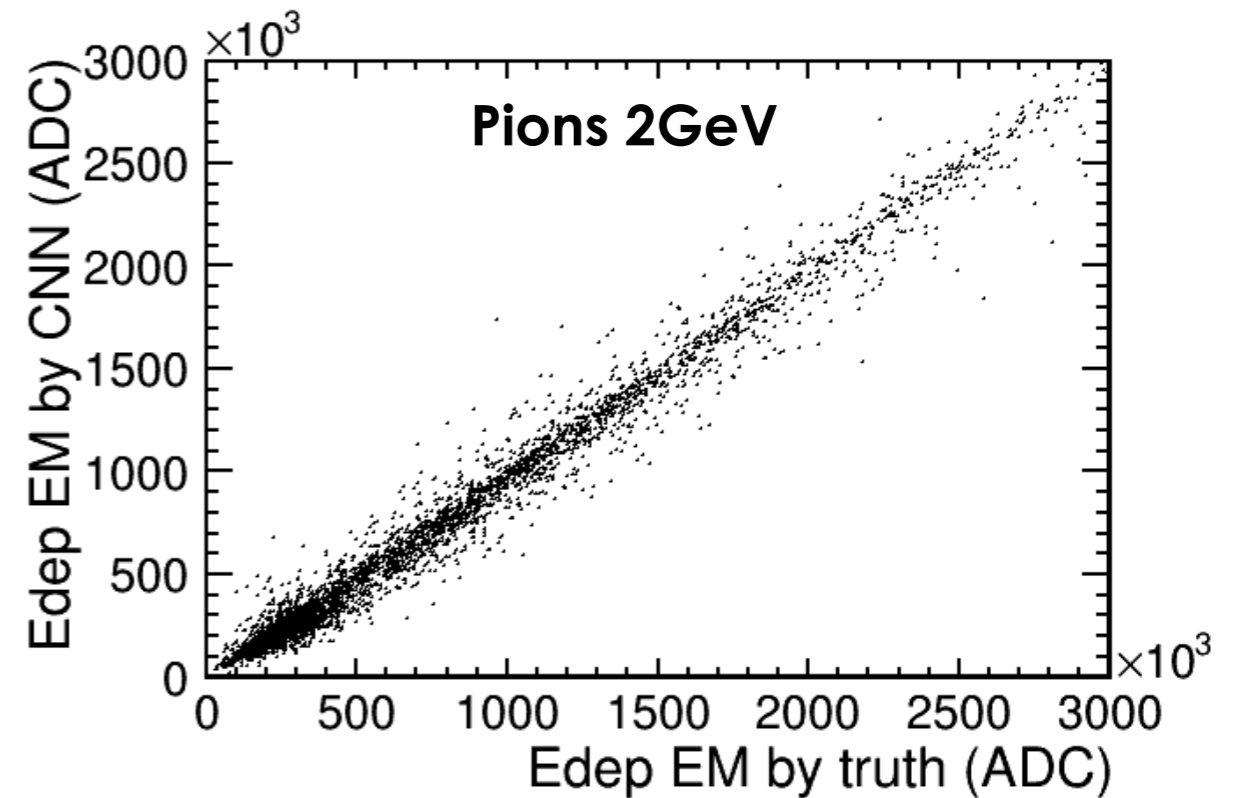
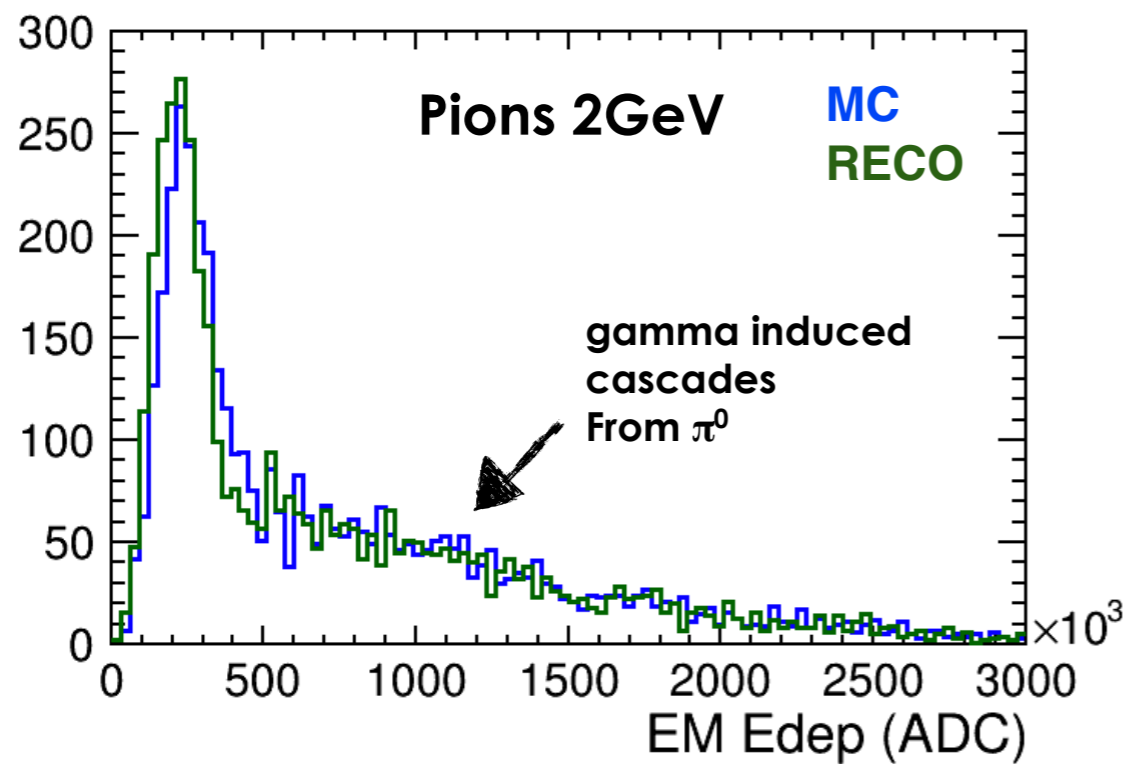
Proton 2GeV

View 1



— Track-like    — EM-like    — Michel.    — Unclassified

# A look into the EM activity

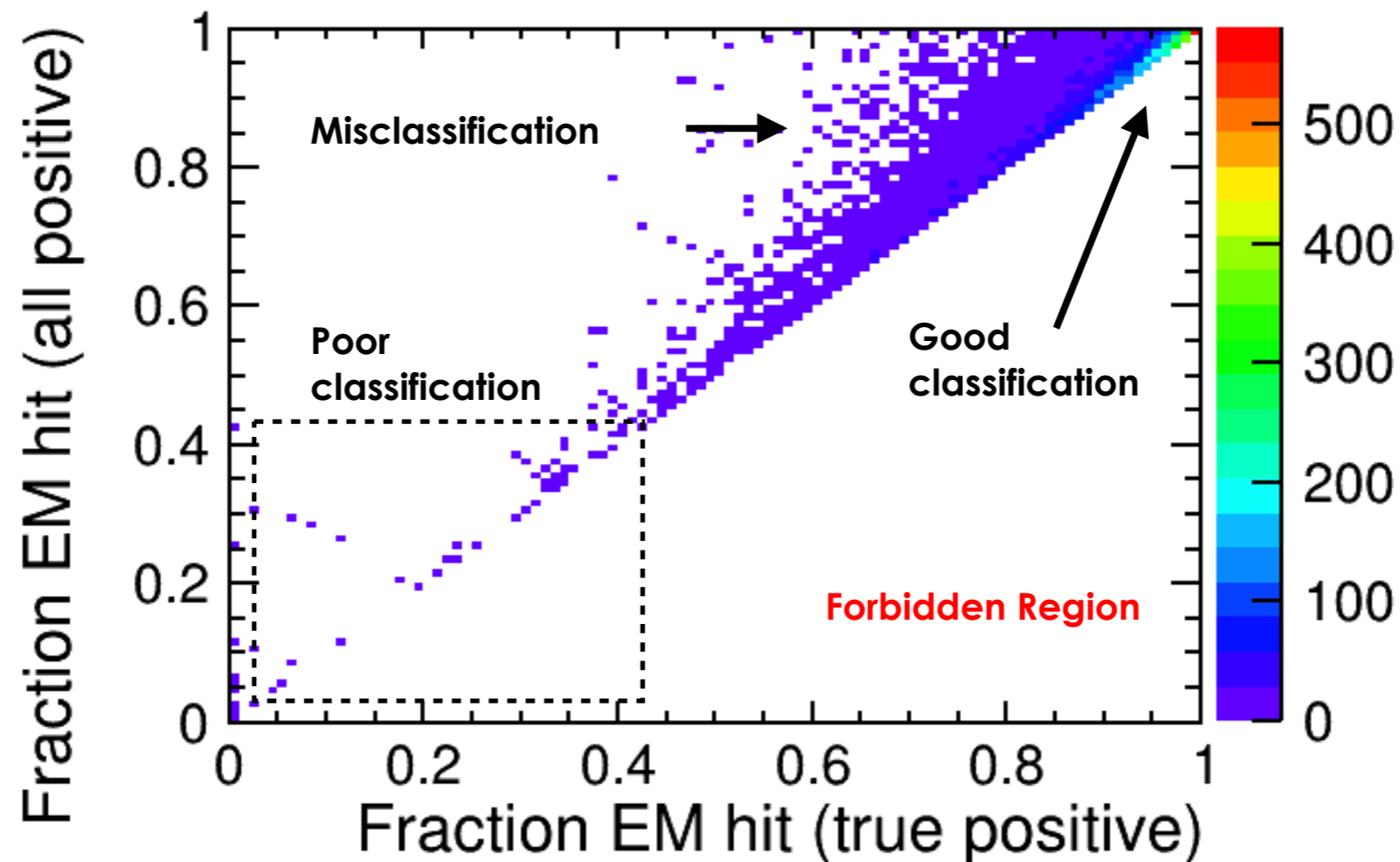


# EM hit purity

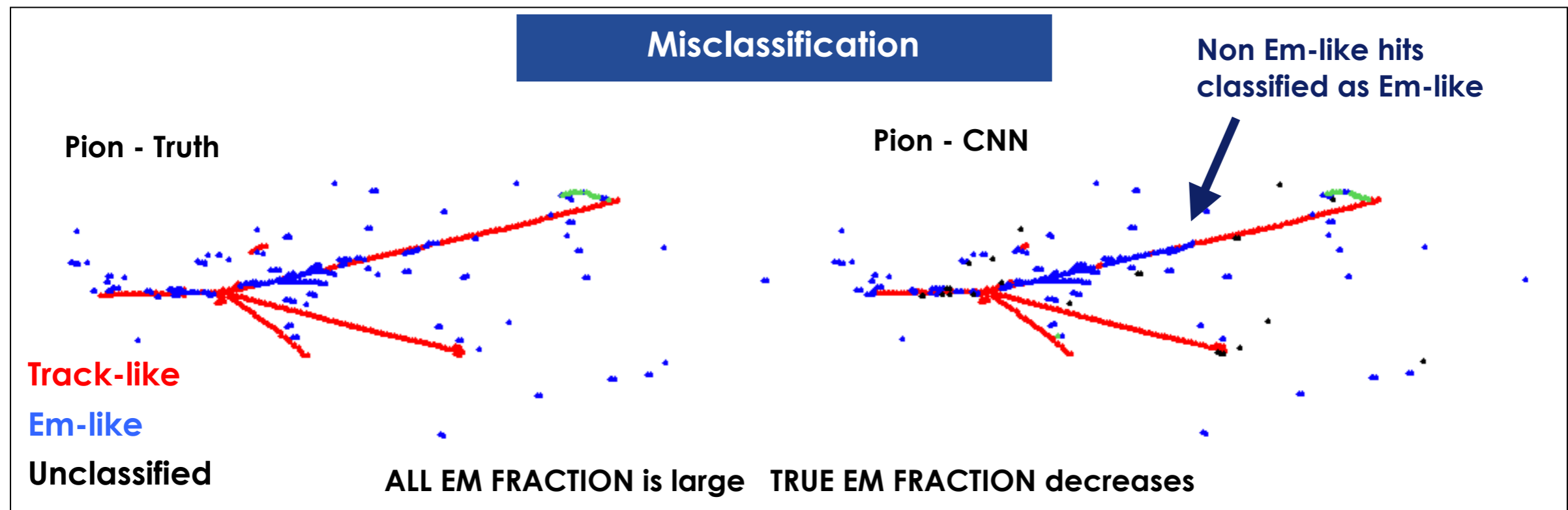
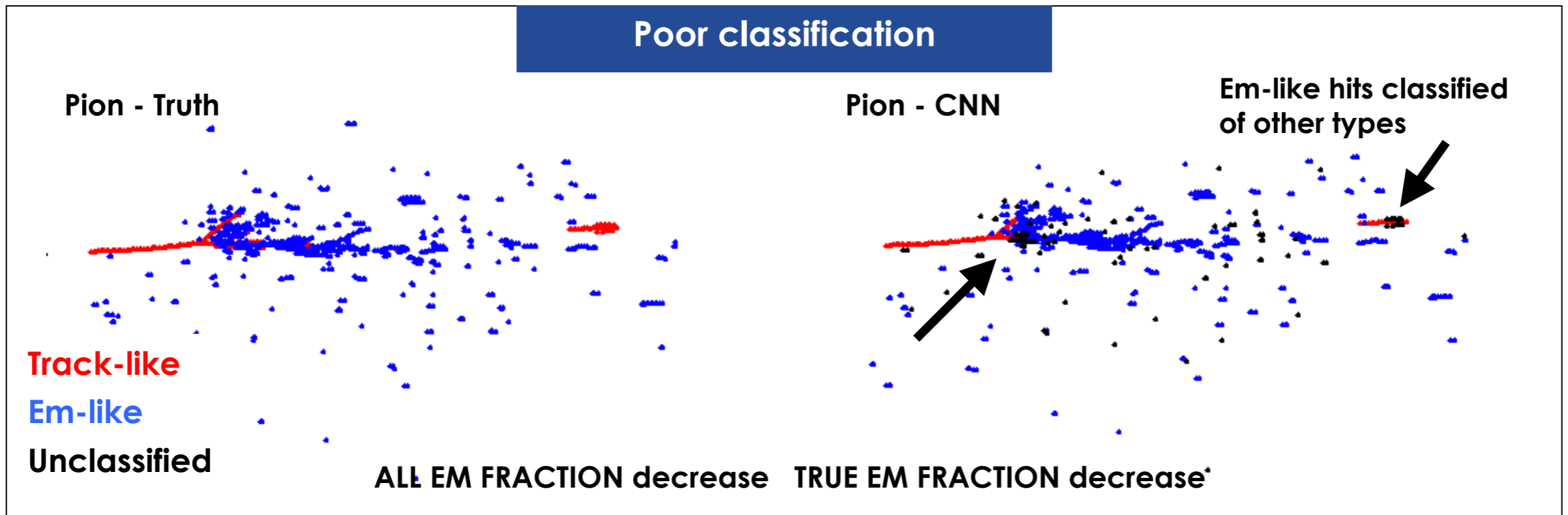
ALL POSITIVE: Hit classified EM by the CNN

TRUE POSITIVE: Hit classified EM by the CNN and confirmed by Truth

Normalized over  
true EM Energy  
Deposit



- Some misclassified hits (labelled by the CNN as EM-like but actually of other type)
- Very few events in the Poor classification region

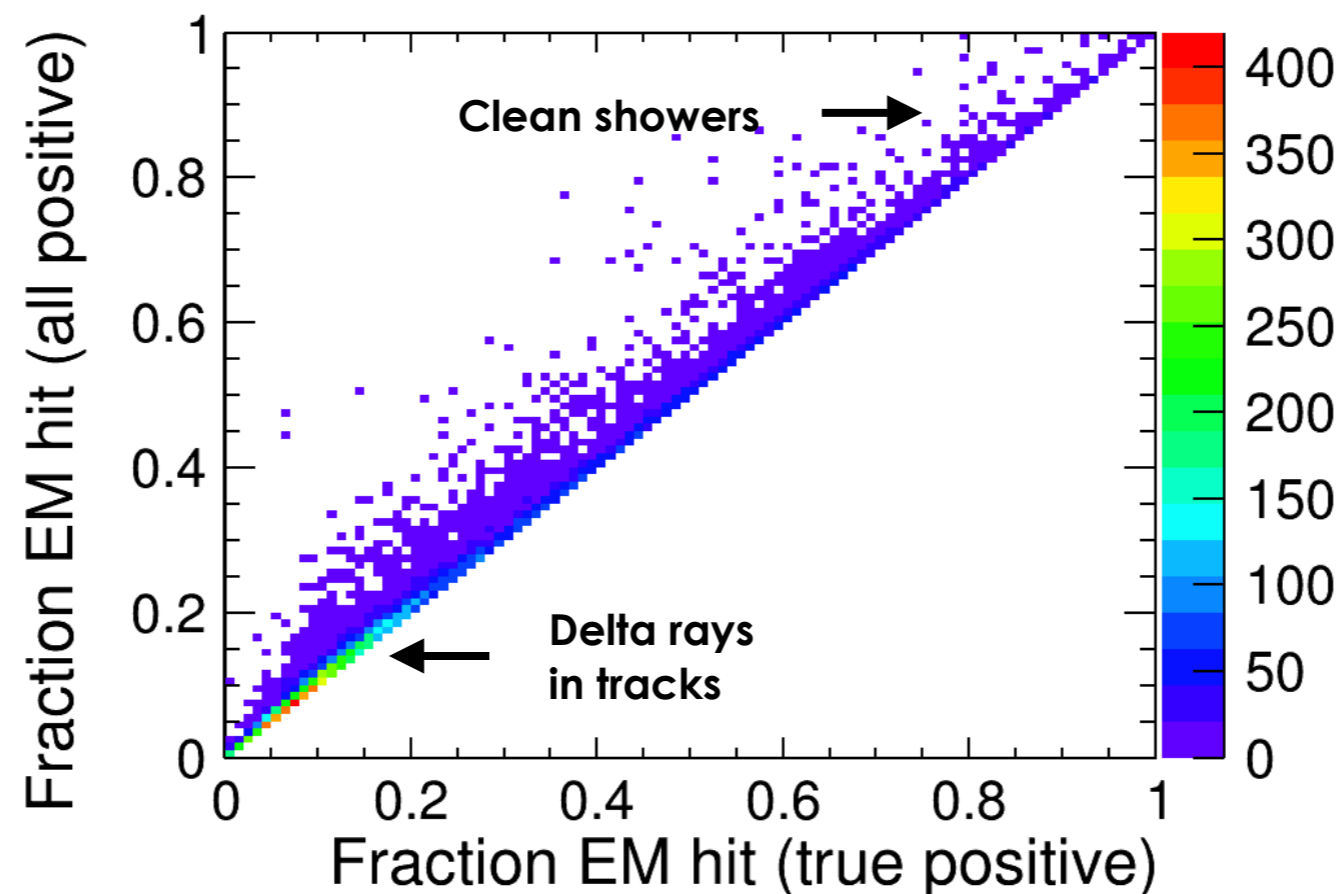


# EM energy fraction

ALL POSITIVE: Hit classified EM by the CNN

TRUE POSITIVE: Hit classified EM by the CNN and confirmed by Truth

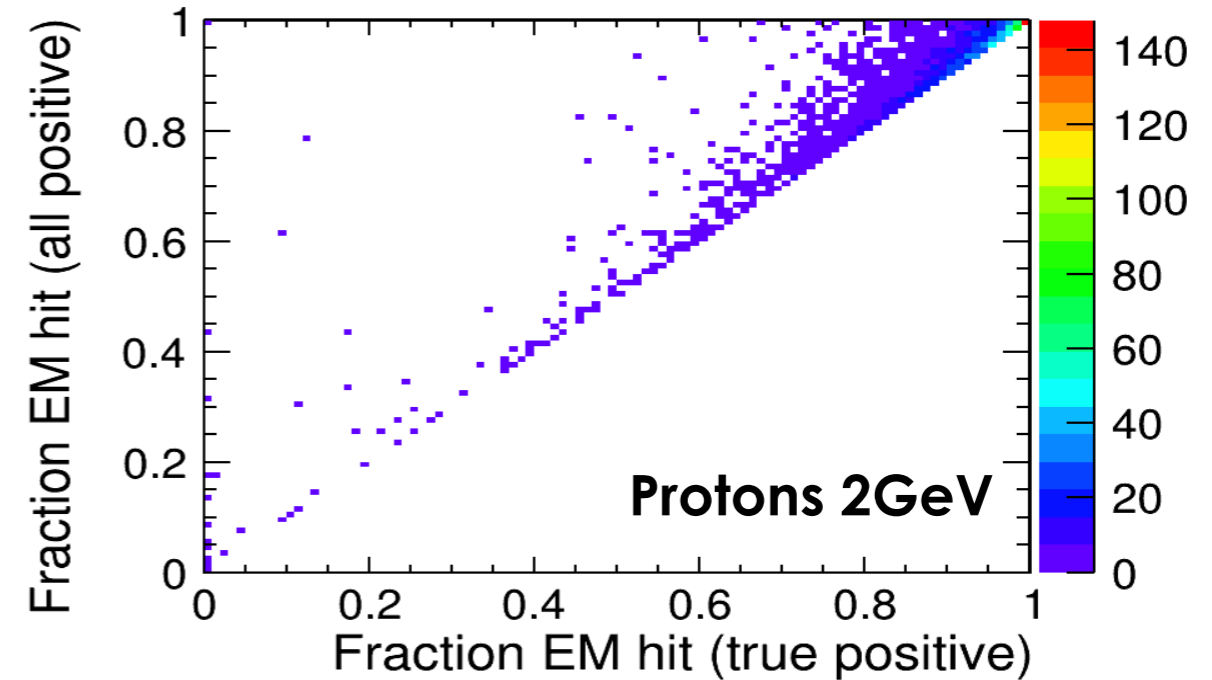
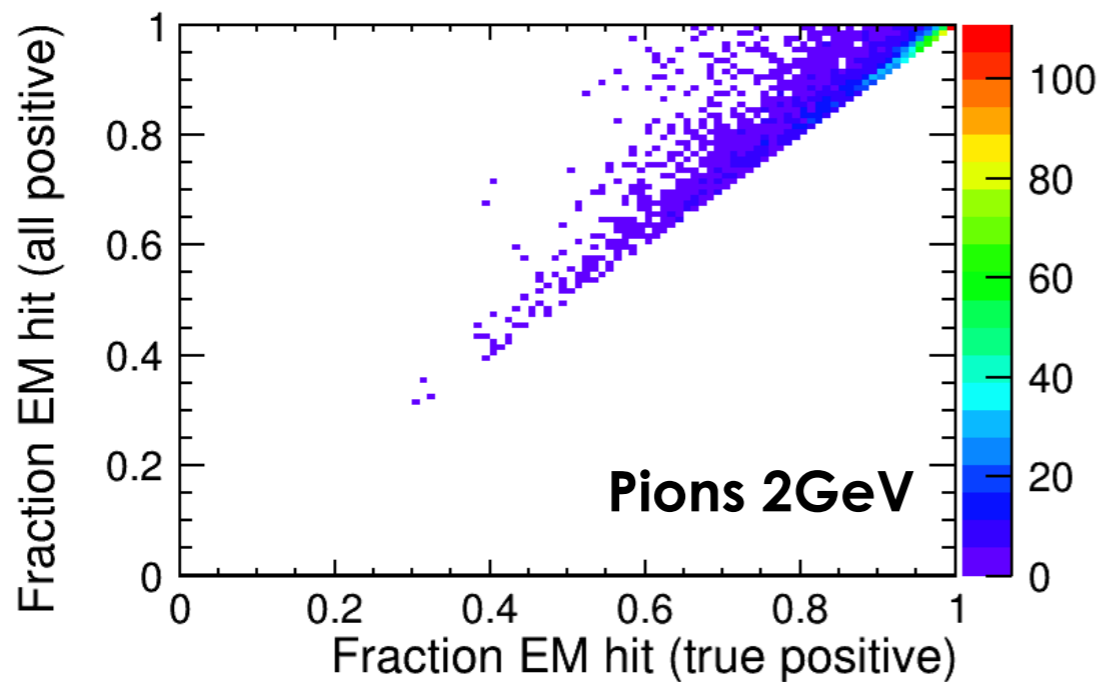
Normalized over  
total Energy  
Deposit



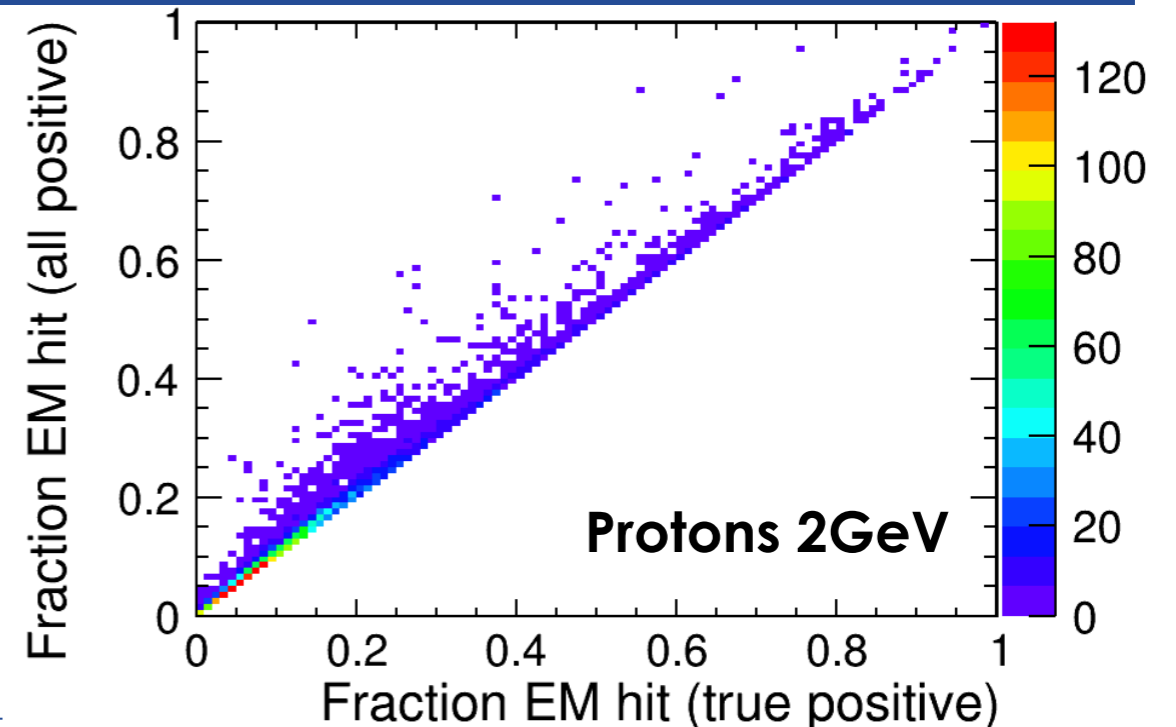
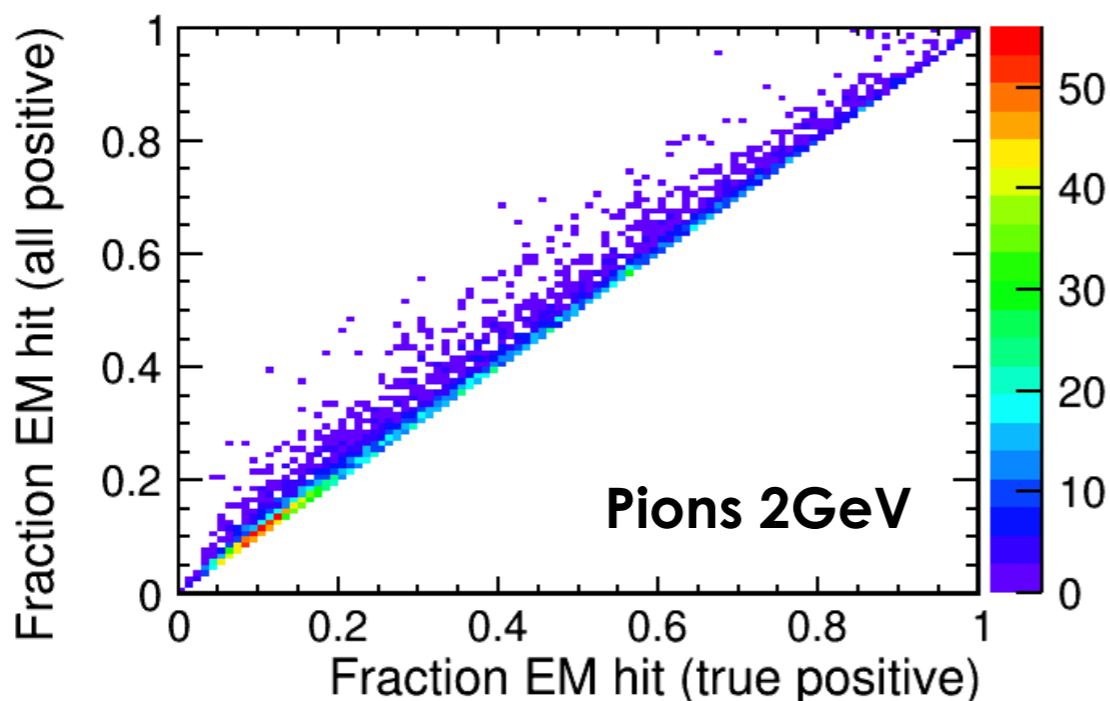
- **On the diagonal:** hits are correctly classified
- **Lower fraction of EM energy deposit:** delta ray deposit in track like events
- **Off-diagonal:** hit are misclassified. **Pretty the same for all the em energy fraction**

# Particle-type hit EM purities

Normalized over true EM Energy Deposit

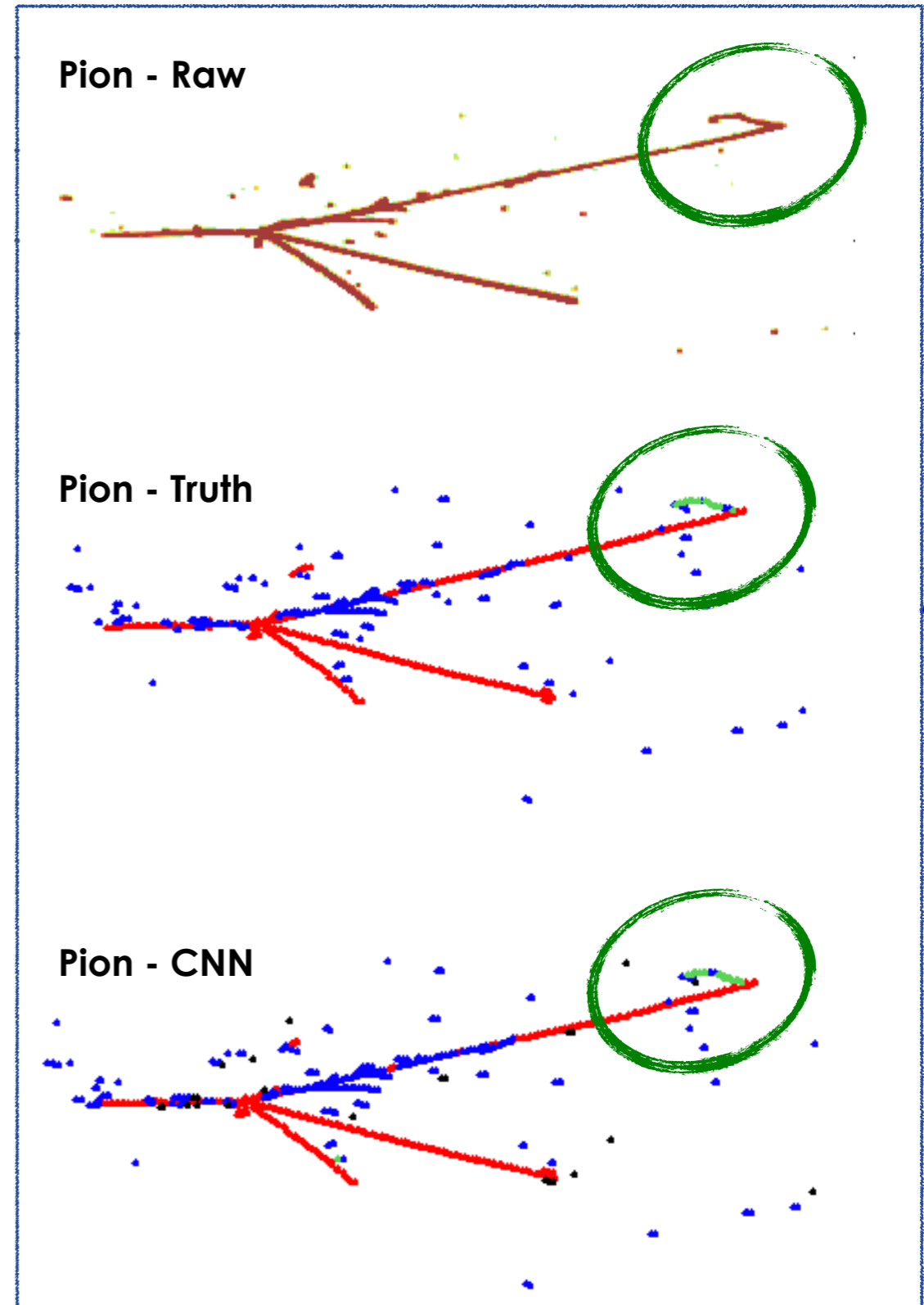
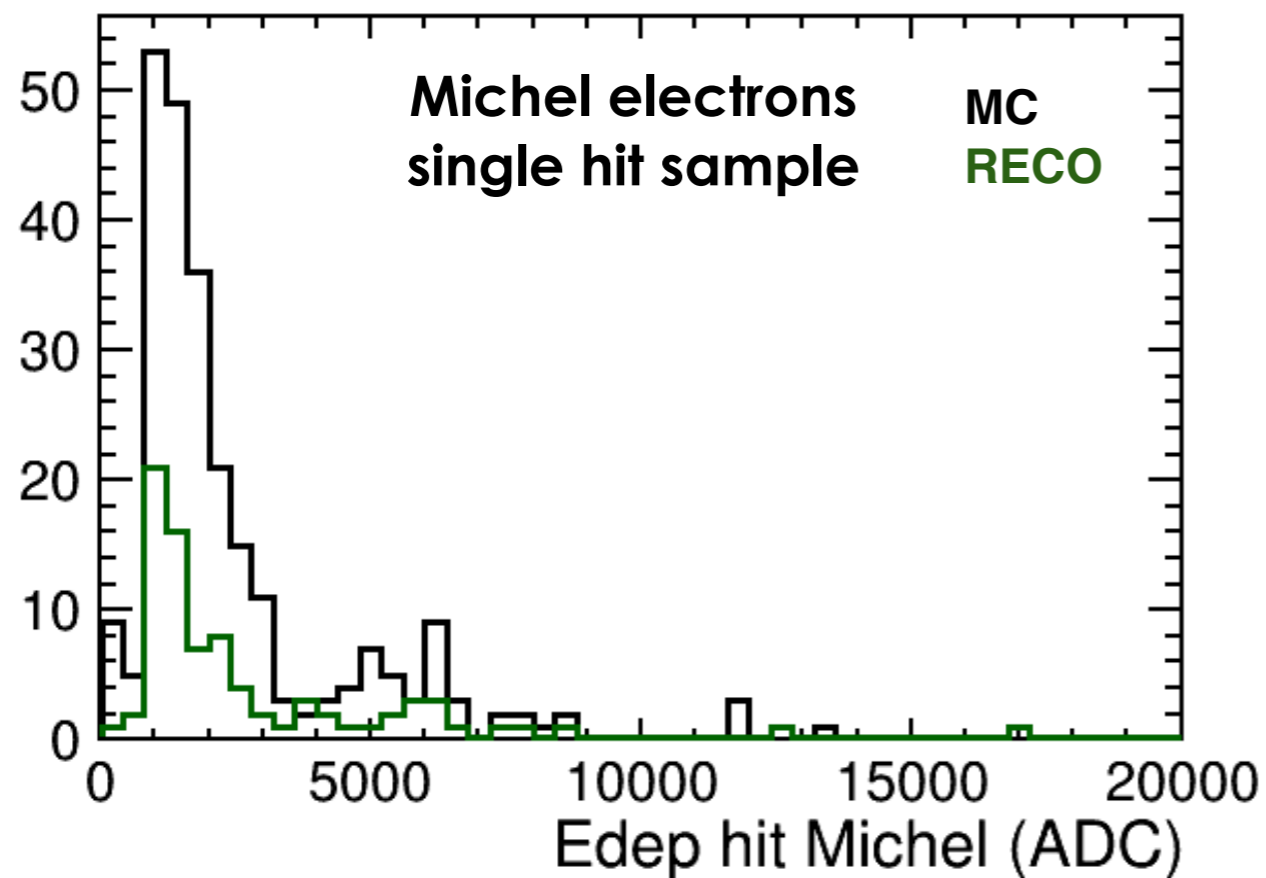


Normalized over total Energy Deposit



## Michel electrons from muon decay

- Only in pion sample
- Difficult for the detector  $\sim 50$  MeV
- Different sample or larger statistic



## $\gamma$ rejection (in progress)

- Studies on conversion gap detection in ProtoDUNE
- For the moment sample of pions and protons
  - Detection of the gap based on clustering after network result (naive approach)
  - Apply more advanced reconstruction algorithms to target type events

## Michel electrons ( in progress )

- ✓ Rotated the cosmic generation (I can have a sample of cosmic muon coming from the right direction)
- Use the brand new 3x1x1 geometry
  - Application on 3x1x1 prototype (with hopefully real data)
    - Noise effects on the network classification
    - Validation of the network approach for DP



## I have tested the application of a CNN for shower/track separation in DP

- Nice separation and the models i tested seems performing well
- Some improvements and tests could be made trying to exploit the better resolution of dual phase
- Work on  $\gamma$  rejection (in 6x6x6) ad Michel electron reconstruction (in 3x1x1) is on progress.

Thank you!

Backup slides

# INPUT PATCHES: examples

